Simulation of cold-formed steel structures

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Buildings framed from cold-formed steel members are becoming increasingly common. Simulation of cold-formed steel (CFS) structures in this dissertation includes seismic modeling and analysis of a two-story CFS-framed archetype building from the CFS-NEES project and shape optimization of CFS columns for maximum strength. The CFS-NEES research project is a joint effort that includes experimental and computational efforts with the objective of providing all the necessary building blocks to advance the simulation tools for seismic performance-based design evaluations of CFS-framed buildings. The simulation effort, which is a major focus of this thesis, includes the development of a wide breadth of finite element models in OpenSees of the CFS-NEES archetype building, calibration of models with full scale shaking table test results, and the exploration of the relationship between model fidelity and prediction of building response. Results indicate that high-fidelity models with consideration of structural and nonstructural components offer reasonably accurate prediction of the archetype building's seismic response in comparison with tests. Nonstructural components in design assumptions, including exterior gravity wall sheathing, interior gypsum sheathing, and partition walls have a significant contribution to the building system's lateral force resistance – and this may be captured in simulations. The performance of 3D models is considerably better than isolated 2D wall line models because of non-trivial coupling effects from the diaphragms, even though existing standards would designate the building diaphragms as flexible. Incremental dynamic analysis results of archetype models are post-processed following the procedure in FEMA P695 for performance evaluation of seismic response modification coefficients employed in design. A companion effort on the shape optimization of CFS columns includes unconstrained and constrained search for a cross-section profile that can maximize the axial capacity with a given sheet of steel. Unconstrained optimization includes comparison between gradient-based vs. stochastic search algorithms and constrained optimization involves implementing a number of end-use and manufacturability constraints into stochastic search algorithms. A number of novel cross-section shapes with considerable capacity growth have been identified, and there is little compromise of capacity after the introduction of constraints. The combined simulation work in this dissertation extensively explores the usage of state-of-the-art computational simulation tools in analysis and design of CFS-frame structures. Research outcomes are compared with test data, commercial products, and existing codes and specifications, and design recommendations are formulated thereafter.

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